Engineering Approaches to Low Vision Rehabilitation

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A poster reporting progress in the first 5.5 years of the project was presented at the 6th annual meeting of the Principle Investigators of the NIH BRP grants.
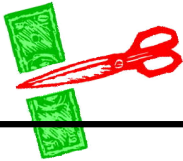*July13-14, 2005, Bethesda, MD*

SPECIFIC AIMS

- Apply engineering approaches to develop optical and electronic devices that aim to restore (at least in part) the important interplay of central (high-definition) and peripheral (wide-field) vision

- Investigate the capabilities and limitations of vision multiplexing techniques

- Develop visual aids that can be dispensed

- Fit patients with the aids

- Train patients in the use of the aids

- Evaluate adaptations

- Test performance in real-world tasks

- Challenge aids in virtual environments.

- Transfer knowledge to the community

PARTNERS

Device Development:
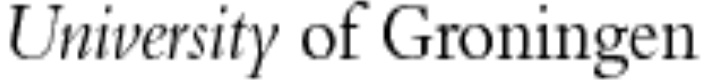
MicroOptical CORPORATION

CHADWICK OPTICAL INC.

DigiVision

Device Evaluation – Real Environments:

University of Groningen

BIVV Belgian Road Safety Institute
Belgisch Instituut
voor de Verkeersveiligheid vzw

University of Rhode Island

BC

UAB department of ophthalmology
driving assessment clinic

University of Pittsburgh

A Teaching Affiliate of Harvard Medical School
Massachusetts
Eye and Ear Infirmary

Device Evaluation – Virtual Environments:

VA Boston Healthcare System

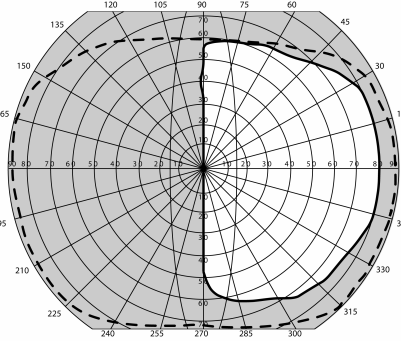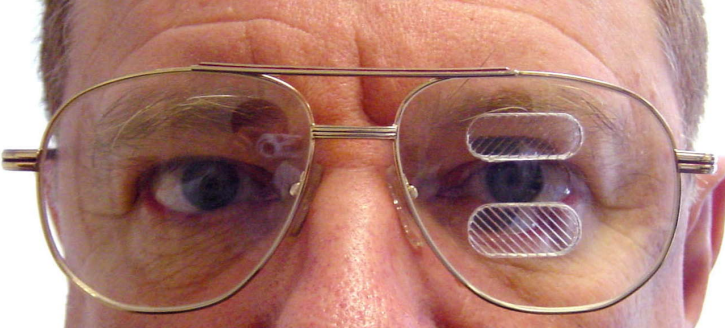THE UNIVERSITY of York

LIGHTHOUSE INTERNATIONAL

PRODUCTIVITY/ACHIEVEMENTS – First Funding Period

- Ophthalmic Journals — 19
- Vision and Neuroscience Journals — 13
- Engineering Journals — 14
- Conference proceedings — 25
- Conference Presentations — 57
- 6 Keynote presentations, including:
  - ECVP – European Conference on Visual Perception
  - Eurosight – European Low Vision conference
  - NOG – Dutch Ophthalmological Society
  - NORA – Neuro Optometry and Rehabilitation Assn.
  - IEEE – Workshop on Computer Vision Applications for the Visually Impaired

- Book published: "Driving with confidence: A practical guide to driving with low vision"
- 7 awards including:
  - AAO Fry Award
  - OSA and SID Fellow
  - Bressler Prize in Vision Science
  - Honorary doctorate from SUNY
- Paper Highlighted in Nature Reviews
- Video (Hope in Sight) received the Telly Award
- 2 patents awarded & 2 more filed
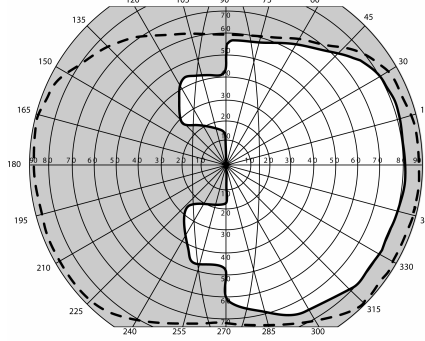- 5 SBIRs awarded to further develop technologies

Device Development

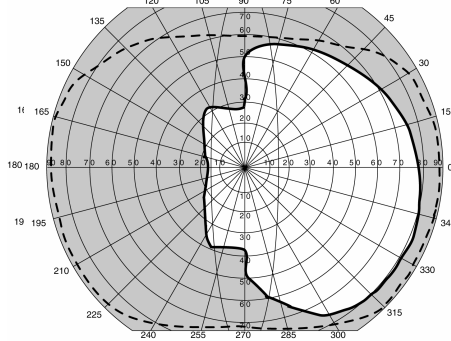## Oblique Peripheral Prisms for Hemianopia

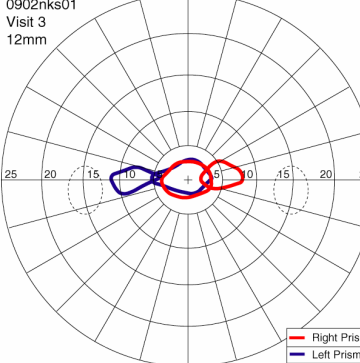### Phase 1 & 2 SBIR Awarded

Without Prisms

Horizontal Prisms

Oblique Prisms

Trifield Prisms for Tunnel Vision

0902nks01
Visit 1
12mm

0902nks01
Visit 3
12mm

Right Eye
Left Eye

Right Prism
Left Prism
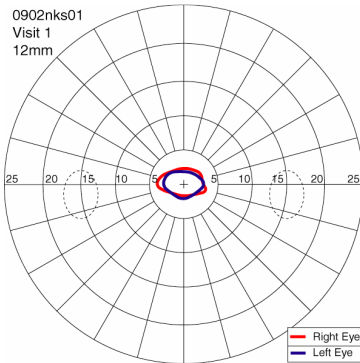
In-Lens Telescope

Phase 1 SBIR Awarded

File =   TX_KEY.2DV
Scale =   3.00
SPHERIC Mirrors Eye Relie 2

33.333   mm

Better Performance

- Curved & flat mirrors
- 4.0x, 24 x 6 deg
- Carrier lens - **5** mm
- SBIR phase 1 awarded for one design
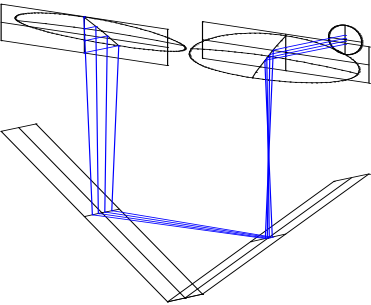
Conventional Telecope

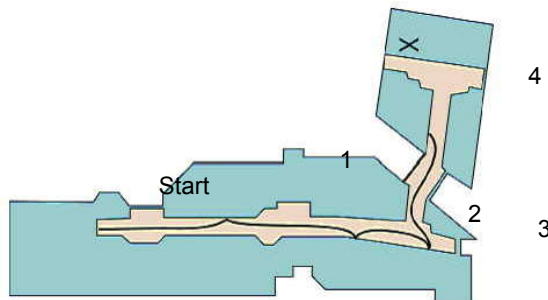Multiplexing

Real-World Testing

On-road Driving

UAB

On-the road trials in a dual-control car in The Netherlands (with U of Groningen), in Belgium (with the Belgian Road Safety Institute), Alabama (with UABirmingham), and Rhode Island (with URI).
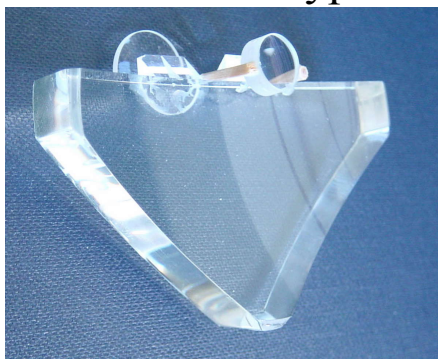
Shopping Mall and Busy Intersection

Orientation and Mobility testing in a large shopping mall and crossing a busy intersection. Completed by Boston College. Data analysis ongoing.
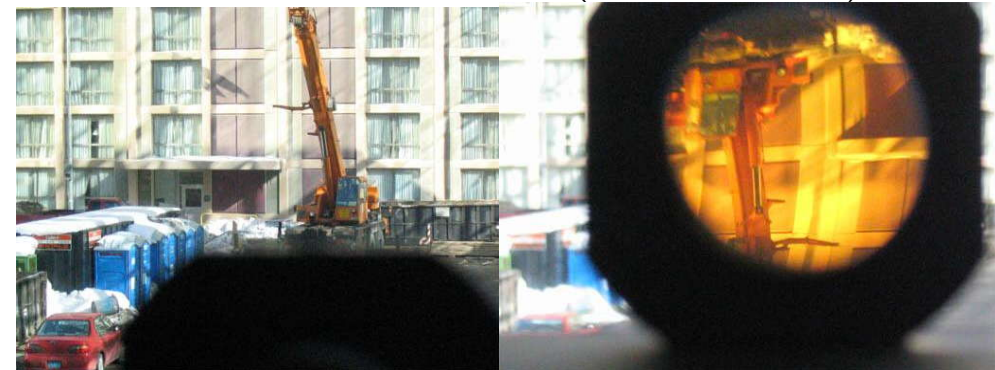
Crude Prototype

It Works!

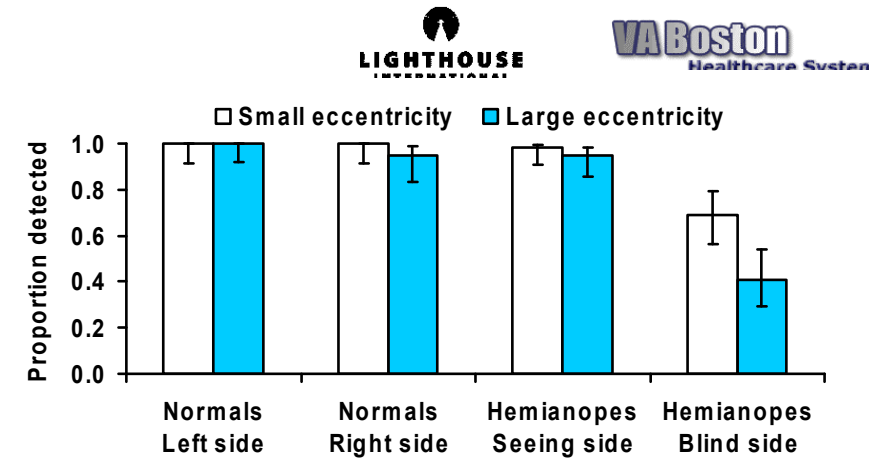### With Parabolic Mirrors (but distorted)
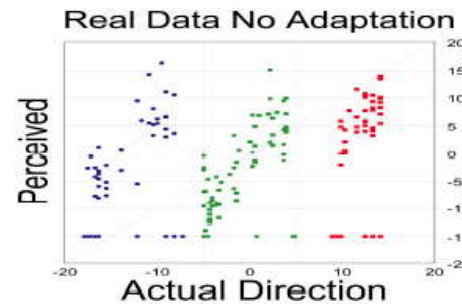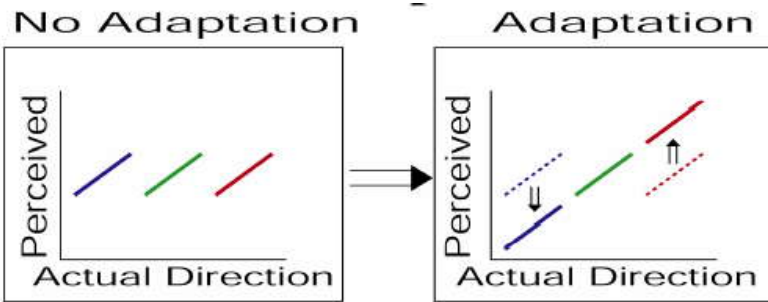
Virtual-World Testing

5-Screen Driving Simulator

Driving scenarios designed to test specific situations for people with hemianopia (with and without prisms) and low acuity (with and without bioptic telescopes).

Adaptation to Visual Direction Using Trifield Prisms

Subjects pointed to vertical line targets
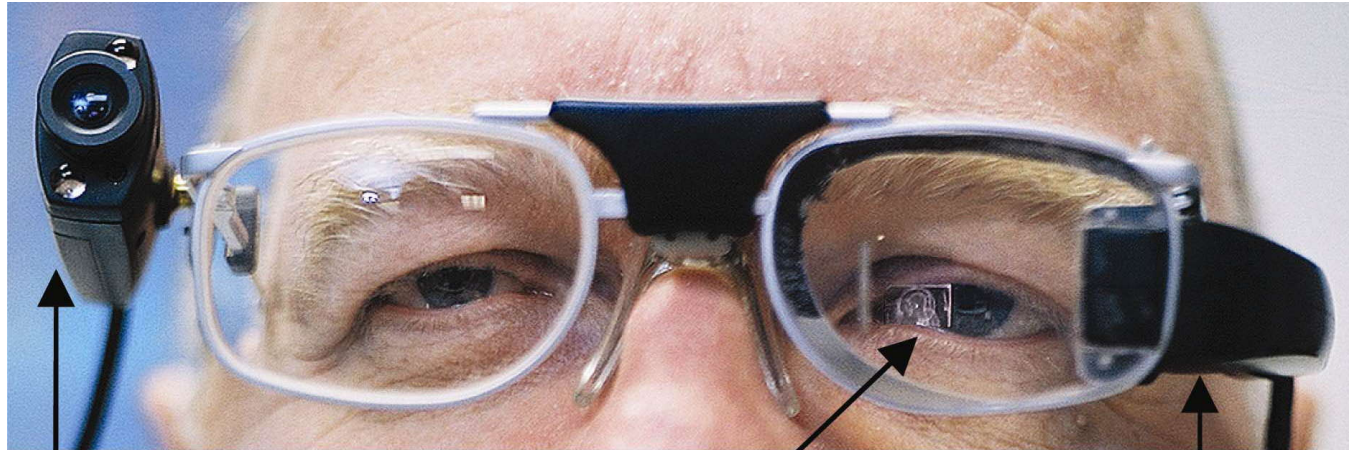No adaptation found

Additional Studies

- Treadmill walking simulator of shopping mall for safe, repeatable tests
  - developed adaptive control for effortless self-paced walking speed
- Survey of AMD patients' bioptic use patterns and driving habits
- Multi-site clinical trial evaluating peripheral prisms: 50 patients enrolled in 16 community-based clinics; >70% chose to continue wearing prisms
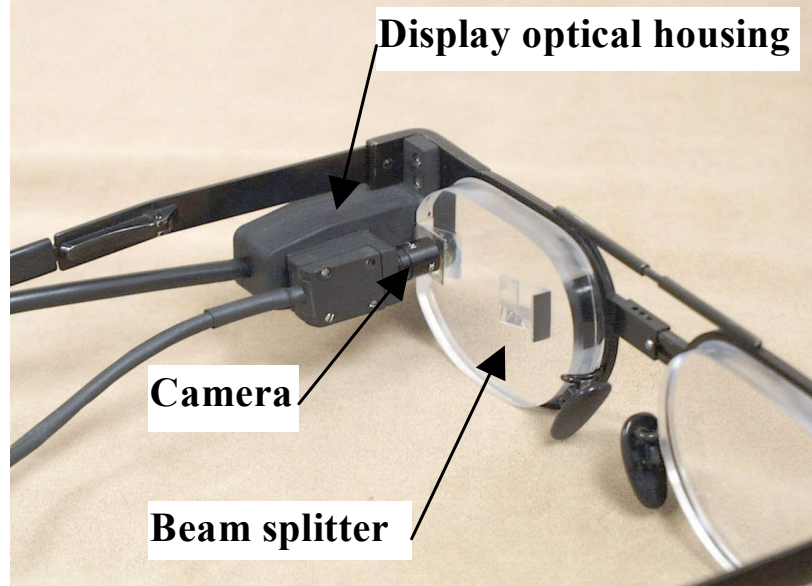
Vision

Augmented Vision

MicroOptical THE CORPORATION

- Day and night versions developed
- A center mark in the minified view facilitates orientation

Camera   Contour image   Display housing

On-Axis See-Through Head Mounted Display

Display optical housing

Camera

Beam splitter

On-axis alignment of the camera and display registers the virtual scene with the real scene.

EYEGLASS LENS   QUARTER WAVE PLATE

LCD   POLARIZING BEAM SPLITTER

BACKLIGHT   CONCAVE MIRROR FOR MAGNIFICATION

A. DISPLAY SYSTEM INTEGRATED IN EYEGLASS LENS

PUPIL

S-POLARIZER   P-POLARIZER

CAMERA LENS

IMAGE SENSOR   PUPIL

B. CAMERA SYSTEM INTEGRATED IN EYEGLASS LENS

PUPIL

C. CAMERA AND DISPLAY SYSTEM INTEGRATED IN EYEGLASS LENS

University of Pittsburgh
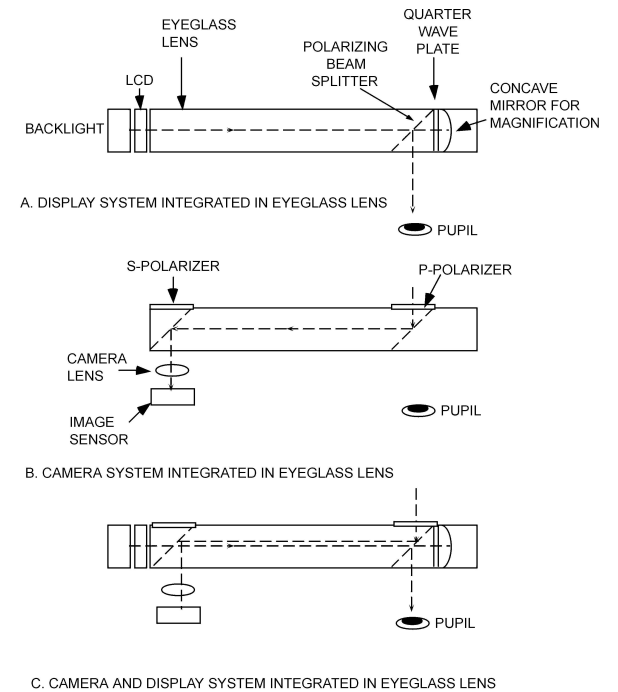
- Night-vision spectacles were tested under different illumination levels
  - on an indoor obstacle course
  - on city streets and dark alleys
- Developed protocol for evaluation
- Testing in extended at-home trials
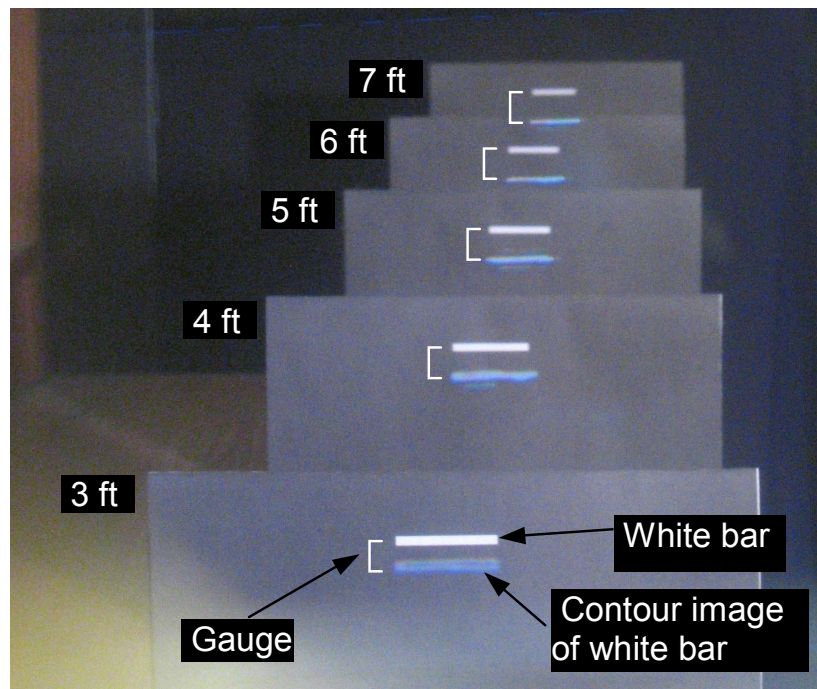
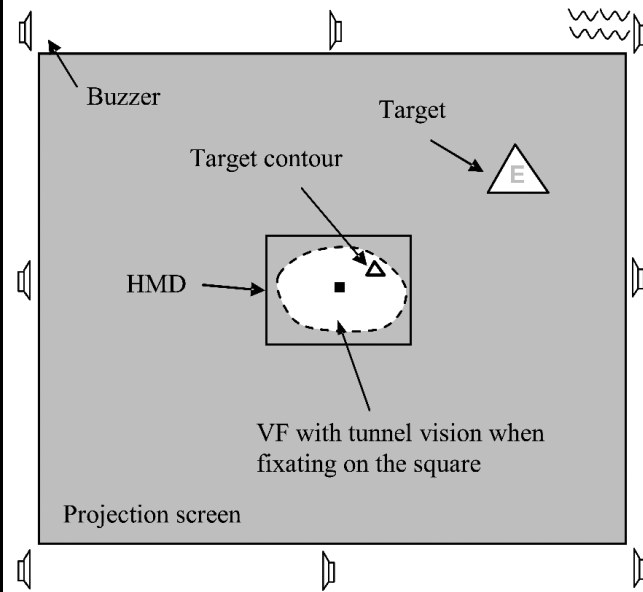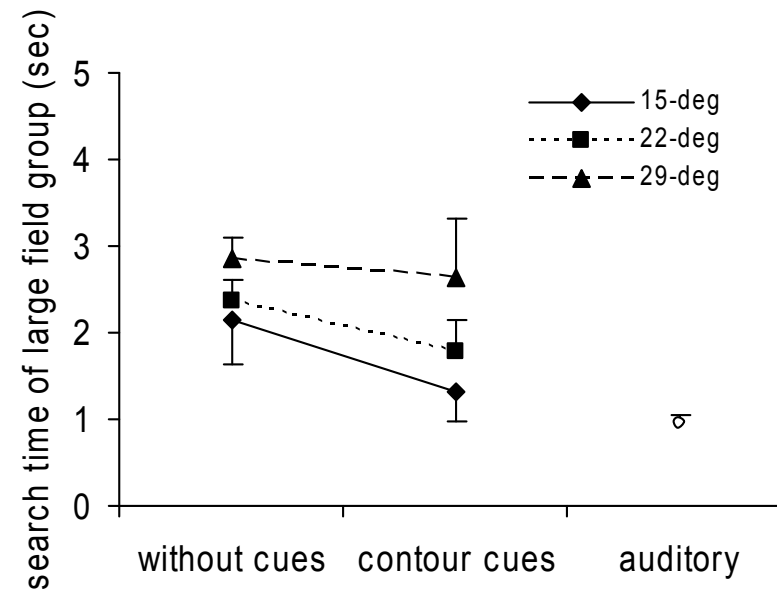Registration of the virtual scene (blue bars) with the real scene (white bars) is critical in many augmented-vision applications, especially when targets are at multiple distances. (The bars are purposely offset vertically in this test image so they can be distinguished.)
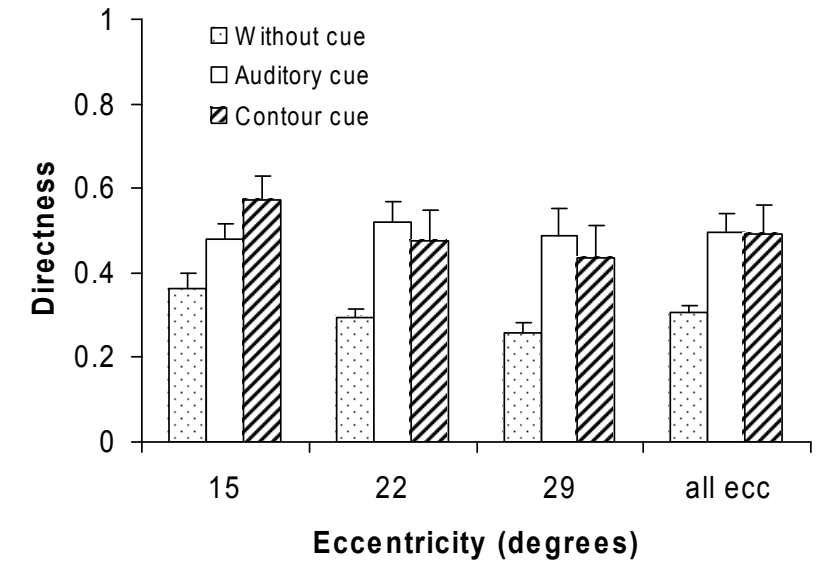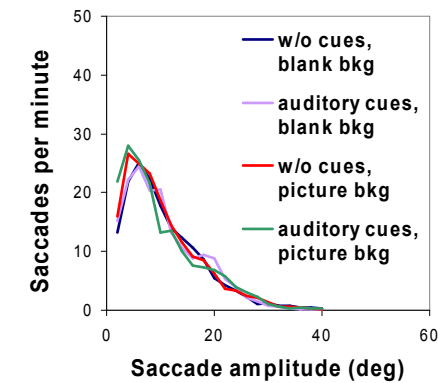
Visual Search Task

Visual search setup

Buzzer

Target

Target contour

Target

E

HMD

VF with tunnel vision when fixating on the square

Projection screen

Search time performance

search time of large field group (sec)

- ◆— 15-deg
- ■···· 22-deg
- ▲-- 29-deg

without cues   contour cues   auditory

Directness of search

Directness

- □ Without cue
- □ Auditory cue
- ▨ Contour cue

15   22   29   all ecc

Eccentricity (degrees)

A patient uses the minified view in the augmented-vision spectacles to locate a target outside her peripheral field, and then turns her head to center the target in her unaided view. A letter in the target is not distinguishable in the minified view. The HMD contour cue reduced the search times of 6 subjects with fields larger than 10º (VF = 12º-16º) by an average of 22% and it significantly improved the search directness of all nine subjects (VF = 7º-16º). Auditory cues to the octant of the target reduced average search time by 54%.

Saccades per minute

- — w/o cues, blank bkg
- — auditory cues, blank bkg
- — w/o cues, picture bkg
- — auditory cues, picture bkg

Saccade amplitude (deg)

The field of view after one third of all saccades had no overlap with the patient's visible field at saccade onset!

Image Enhancement

Inattentional Blindness

(a) When following a hand-slapping game, subjects often missed the umbrella woman strolling through the ball game. (b) & (c) Edge filtering had no effect on unexpected event detection rates. Unexpected events in the attended scene were always detected.

- When concentrating on a task, people frequently fail to notice highly visible unrelated events
- Can this be mitigated when vision multiplexing?
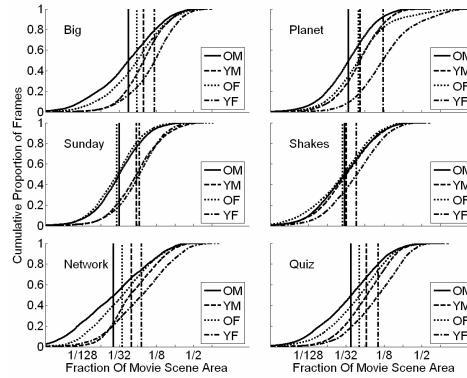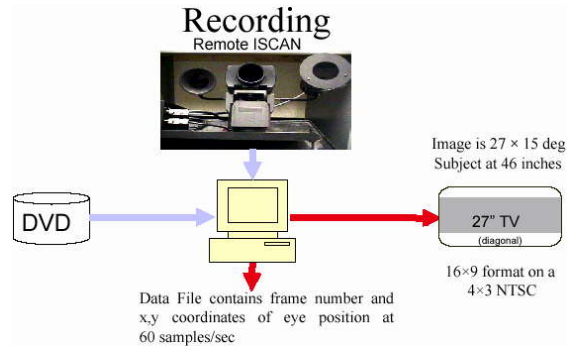
MPEG Enhancement
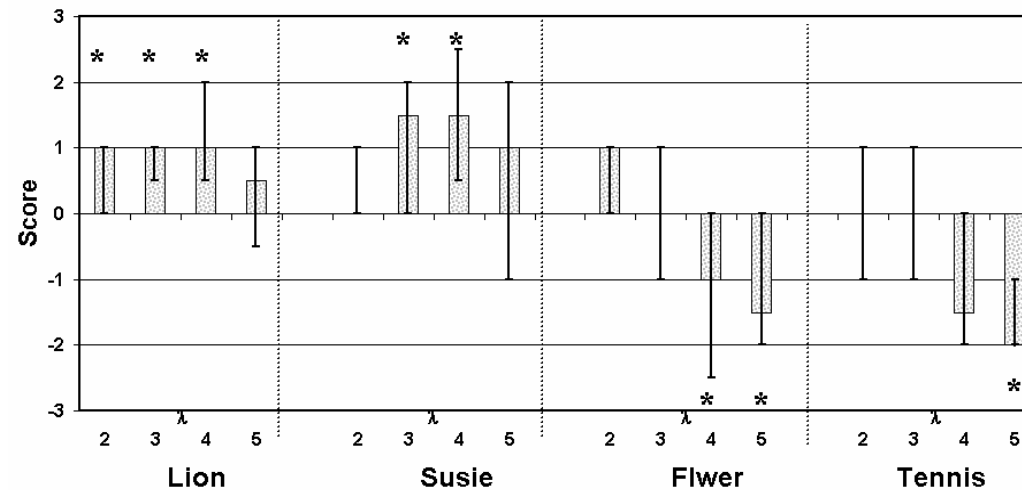
Patients favored enhanced videos with moderate motion, and rejected videos with much motion. A real-time implementation that runs on a desktop PC won a distinguished poster award at SID2005.

Dynamic Control of Magnification

Point of Regard Established by Monitoring Normal Viewers

The cumulative distribution show that all movies viewers generally look at the same small area of the screen in every frame. While the older and males groups are more consistent within each group than younger and females groups, respectively, most observers look at about the same place. Therefore, centering the magnified image on an average position should be useful.
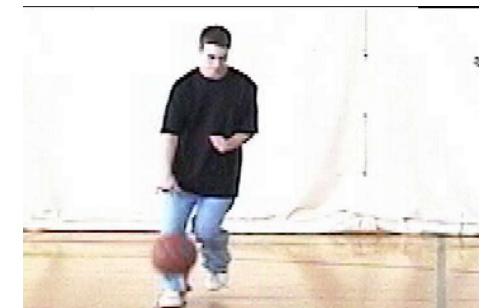
Point of Regard Then Controls the Center of Magnification
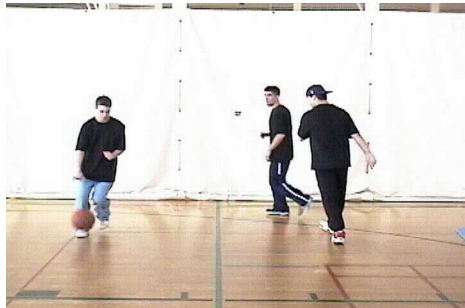
Features in the normal video are too small for people with poor visual acuity

Even 2 x magnification (left) around the center often loses the interesting part of the scene, but magnifying around the Point of Regard is most satisfying (right)

Bipolar Edge-Filtered Image Provides Context

- It is easy to lose context with a magnified view.
- We developed a filter that processes the video to produce cartoon-like images with just the edges of the features of the full frame. Overlaying the magnified view with the full-view edge images maintains context. All edges are bipolar (black and white), so they show against both light and dark backgrounds.

Administration and Management

- Website with publications, presentations, and media coverage:
  http://www.eri.harvard.edu/faculty/peli/index.html

- Website for data sharing:
  http://www.eri.harvard.edu/faculty/peli/shared/index_page.htm

- Microsoft Access database application to update 6-month project review

- Web-accessible calendars for individuals, and to schedule
  meeting rooms, lab spaces, and patient visits

- Generation and maintenance of lab protocols on web-accessible site for:

  - equipment setup and operation
  - vision measurement methodology
  - reusable code and techniques
  - code management/revision control
  - electronic backups
  - off-site electronic archives